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CHANGES IN QUALITY OF EGGS PRODUCED IN HAWAII

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CHANGES IN QUALITY OF EGGS PRODUCED IN HAWAII

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The quality of eggs offered for sale on the Honolulu market is of concern to the producer, merchant, and consumer. This consideration has resulted in rules and regulations concerning egg grades of both locally produced and imported eggs. Standard grades have been promulgated, and these are enforced by the Division of Marketing of the Territorial Board of Agriculture and Forestry (*22*). Furthermore, certain staff members of the College of Agriculture, University of Hawaii, have recurrently emphasized the need for proper handling of eggs, with particular stress on preservation of egg quality (*3*). In numerous references from the Mainland one can also find similar recommendations concerning the maintenance of egg quality (*5, 14*). Indeed, it is common knowledge that frequent collections daily, storage in open wire baskets, prompt refrigeration, and biweekly marketing will assist materially in maintaining egg quality, and consequently should enhance consumer preference for locally produced eggs.

However, there are numerous instances of disregard on the part of producers, merchants, and consumers for the preservation of egg quality. It would appear that the responsibility for maintenance of egg quality is always the next man's in the channel of trade. Since the egg is at its best when laid, it is obvious that the preservation of an egg is the responsibility of each party, in turn, as the egg is carried from the hen to the consumer.

How rapidly do eggs deteriorate in Hawaii? Surprisingly little information on this point was available. A paucity of information existed in the literature, as well, concerning the day-by-day changes in egg quality. This study was undertaken, consequently, to fill in the gap, with particular reference to Hawaiian conditions, and to serve as a standard in evaluating the relation between egg storage and quality deterioration.

SURVEY OF THE LITERATURE

Effect of Hen on Egg Quality

In a study of the effects of seasons on egg quality, Lorenz and Almquist (*13*) reported that the environmental temperature during the time eggs are being formed had no noticeable effect on the percentage of "firm" white, while the temperature immediately after oviposition had a distinct effect. Knox and Godfrey (*10*) found that earlier egg production was not significantly correlated with either the total amount of albumen, amount of thick white, or percentage of thick white. Lorenz and Almquist (*13*) have also shown that the association between percentage "firm" white and egg weight was spurious ($r = +.002 \pm .093$) when an analysis was made using eggs from hens selected at random. Jull and Byerly (*9*) stated that subsequent pullet eggs became watery as eggs increased in size because there was an increase in the weights of yolk and liquid white, while the weight of firm white increased relatively little. Hunter *et al.* (*8*) found that eggs of highest internal quality were produced between November and March and eggs of lowest quality in the spring and summer. Lorenz and Almquist (*13*) contended instead that the increase in weight of liquid white of later eggs from the same birds was probably due to the seasonal increase in temperature, resulting in greater liquefaction of the "firm" white after the eggs were laid. No mention was made by Hunter *et al.* (*8*) of the effect of temperature on egg quality following oviposition.

The quantity of thick white has been found to be influenced by Mendelian factors. In 5 years of selection, Knox and Godfrey (*11*) developed two strains of Rhode Island Reds that differed significantly in percentage of thick albumen in fresh eggs. They concluded that chickens can be bred to produce eggs with large quantities of thick albumen. Berry (*2*) reported that real progress was made through selection from 1946 to 1949 in developing two strains of Single Comb White Leghorns that differed materially in firm albumen content. Eggs produced by the "watery" line were definitely B grade when freshly laid.

Effect of Environment on Egg Quality

There is general agreement that eggs deteriorate readily, the rate of deterioration being dependent upon the interaction between duration of storage, temperature, humidity, and condition of the egg shell. Olsen (*15*) stated that temperature and humidity are probably the two most important factors responsible for maintaining or destroying the interior quality of eggs. Holst and Almquist (*6*) reported that properly controlled conditions can cause a decrease in either water or carbon dioxide in the egg. They stored eggs at 86° F. for 26 days in a desiccator over calcium chloride in an atmosphere maintained at 5 percent carbon dioxide. Although the eggs had air cells ¼ to ½ inch in depth, showing excessive shrinkage, the interior quality was reported excellent. Thick white constituted an average of 52 percent of total white. Other eggs stored in a desiccator over 5 percent sodium hydroxide showed very little shrinkage after 26 days, yet the albumen was badly liquefied. Regarding the effect of storage on the yolk, Sharp (*17*) observed that the longer an egg is stored and the higher the storage temperature, the more the yolk flattens when the egg is opened and the greater its water content.

It has been shown by Olsen *(15)* that infertile eggs stored at 90° F. for 24 hours or at 100° F. for 18 hours contained approximately 9 percent less "thick" albumen than infertile eggs stored at 35° F. for 7 days. Lorenz and Almquist *(13)* reported a difference of 15.3 percent in "firm" white of eggs stored 24 hours at either 40° F. or 86° F., the eggs stored at 40° F. showing practically no change in albumen score. Similarly, Skoglund and Tomhave *(19)* reported a drop in albumen score of 3.23 percent for eggs stored in a trapnest at 83° to 90° F. for 4 hours; of 3.83 percent when eggs were stored 6 hours; and 4.09 percent when eggs were stored 8 hours.

Changes within the Egg

Holst and Almquist *(7)* found that the percentage of solids was the same in "thick" and "thin" white from the same egg whether the egg was old or fresh. They reported that the concentration of water remained the same in each, regardless of losses to the yolk and through the shell. The refractive index, measured with a Spencer Refractometer (Abbe type) was also practically the same. St. John and Green *(21)*, by means of plasticity measurements on individual eggs, postulated a gross colloidal structure for thick white which probably did not exist in the thin white. They suggested a progressive change with age of thick into thin white by a colloidal transformation involving a breakdown of the gross colloidal structure of the thick white. With regard to changes in egg yolks, Holst and Almquist *(6)* suggested that osmotic forces were operative in the transfer of water from the white to the yolk. The water which diffused into the yolk produced two effects, both undesirable: the yolk membrane was compelled to stretch and was weakened thereby; and there resulted a marked increase in the fluidity of the yolk substance.

Methods of Determining Quality

Various methods of determining quality have been reported. By far the most universally adopted technique is that of candling, and official standards of quality have been established both by the United States and by individual state Departments of Agriculture and/or Marketing. Whereas this technique is effective in the main, it is not sufficiently refined to detect small changes in quality, and is subject to the inaccuracy of human vision and psychology. According to St. John *(20)*, candlers frequently agreed that "wateriness" cannot be determined by the candling procedure. Canham

(*4*) found that eggs which appeared firm on candling varied from 25 to 52 percent of thin white, whereas eggs which appeared watery under the candle contained from 18 to 94 percent thin white. The data of Pennington *et al.* (*16*) also showed a variation in percentage thick white, and this variation was not closely correlated with market grade. Almquist (*1*) also reported that yolk shadow and percentage of thick white appeared to be almost entirely unrelated.

Holst and Almquist (*6*), in order to avoid the lack of preciseness of candling, devised a technique of separating the thick and thin albumen by means of a sieve containing 81 openings per square inch, so that the amount of each could then be determined quantitatively. Knox and Godfrey (*10*) developed an apparatus somewhat similar; in their study on egg quality, however, they used a sieve containing 64 holes per square inch. Lorenz and Almquist (*12*) further modified this technique. Other details of construction and manipulation are omitted for brevity but may be obtained from these references. Pictorial techniques have also been utilized by Sharp (*18*) and Van Wagenen and Wilgus (*23*).

MATERIALS AND METHODS

Sixty New Hampshire and 40 Rhode Island Red pullets were selected at random to establish average indexes for the thick albumen and yolks of freshly laid eggs. Within ½ hour following oviposition, all eggs from these pullets were candled for yolk mobility and opened. It was planned to open 10 eggs produced by each pullet. In all, 988 eggs were measured in determining the fresh-egg indexes.

The mobility of yolk was scored as follows: grade 1, non-mobile yolk; grade 2, slightly mobile yolk; grade 3, mobile yolk; and grade 4, highly mobile yolk. In each case, the eggs were firmly rotated back and forth once before the candle,[1] and a mobility score was assessed. The thick albumen content of each egg was measured according to the following technique. The entire albumen was separated from the yolk and the total measured in a graduated cylinder. It was then poured onto a standard Tyler screen,[2] U. S. No. 10, and gently sieved for approximately 60 seconds. The albumen remaining in the screen was then measured and designated thick albumen. The albumen index was then calculated as the quotient of thick albumen over total albumen.

After being separated from the albumen, the yolk was placed on a Petri

[1] PREVUE, Fertility Tester, manufactured by the Breeders' Supply Co., Beachwood, New Jersey.

[2] The W. S. Tyler Co., Cleveland, Ohio.

dish of calibrated thickness and left there until the albumen was measured. The height of each yolk was determined by means of a height caliper, and the average diameter was calculated as the mean of the greater and lesser diameters, using a vernier caliper. The yolk index was then calculated as the quotient of height over average diameter.

Treatments

In series 1, eggs, laid prior to 10:00 A.M. by the 100 pullets from which 10-egg averages had been previously determined, were randomly distributed into two groups and candled for yolk mobility. One group of eggs was subjected to direct sunlight for 4 hours, while the other was stored in a refrigerator. Temperatures were recorded hourly by means of a thermocouple potentiometer (General Electric, PS-1-B4), and averaged. These temperatures are shown in table 2. Following the 4-hour period, the eggs were candled again for yolk mobility, and then opened to determine the yolk and albumen indexes. In a subsequent study, eggs were stored 8 hours instead of 4.

In series 2, eggs were stored 24, 48, 72, 96, 120, 144, and 168 hours. Half of the eggs were stored at room temperature on open "flats," and the other half were stored in a refrigerator at 54° F. The identical procedure of candling prior to and after storage was followed. However, daily temperature readings were taken only at 10:00 A.M. and at 4:00 P.M. Furthermore, eggs destined to be stored 72 hours or longer were randomized into four groups. Two of these were submerged for 30 seconds in No. 3, U.S.P. white mineral oil that was heated to 100° F. A treated and an untreated group were then stored at room temperature, while the other two groups were stored in the refrigerator. The temperatures at which these eggs were stored are shown in table 3.

In series 3, oil-treated and untreated eggs were stored under refrigeration at 54° F. for 7 days. Half of each group was removed and stored at room temperature. The eggs were then candled for yolk mobility and opened 24, 48, 72, and 96 hours thereafter to determine the yolk and albumen indexes. This study was conducted to simulate conditions of holding after the eggs were purchased by the consumer or held for sale by the merchant.

In series 4, both oil-treated and untreated eggs were stored for 31, 59, and 93 days at a temperature of 36° F. to simulate cold storage of eggs. These eggs were graded before and after storage according to the grade standards of the U.S. Department of Agriculture, Production and Marketing Administration.

In all, 4,453 eggs were opened in this study.

RESULTS

The data in table 1 show the average yolk mobility scores, and albumen and yolk indexes of fresh eggs. These eggs had been gathered frequently from 8:00 to 11:00 A.M. and opened within 1/2 hour after oviposition. The data were procured from randomly selected pullets representing two breeds; namely, New Hampshires and Rhode Island Reds. An average of 9.88 eggs was sampled from each pullet, and data were collected from 100 chickens. The values obtained for each breed are shown in table 1. The indexes for yolk mobility, yolk index, and albumen index were uniformly similar, and were not significantly different between the two breeds. When the data from the 100 pullets were combined, the following indexes for fresh eggs were obtained: yolk mobility, 1.61 ± 0.023; yolk index, 0.373 ± 0.014; and albumen index, 0.549 ± 0.017. Such eggs could also be described as follows: yolk observed to shift slightly upon routine candling, the yolk, when completely separated from the albumen, having a height that was 37.3 percent the average of two diameters, and the thick albumen comprising 54.9 percent of total albumen.

TABLE 1. Yolk mobility, and albumen and yolk indexes of eggs measured within 1/2 hour after oviposition.

BREED	NUMBER OF PULLETS	NUMBER OF EGGS	YOLK MOBILITY*		YOLK INDEX†		ALBUMEN INDEX‡	
			MEAN	STANDARD ERROR	MEAN	STANDARD ERROR	MEAN	STANDARD ERROR
New Hampshire	60	597	1.66	0.044	0.377	0.001	0.545	0.005
Rhode Island Red	40	391	1.54	0.048	0.366	0.002	0.556	0.004
Combined	100	988	1.61	0.023	0.373	0.014	0.549	0.017

*Grade 1=non-mobile yolk; grade 4=highly mobile yolk.
†Yolk index=height of yolk divided by average of two diameters measured at right angles. Yolk was free of surrounding albumen when measured.
‡Albumen index=amount of thick albumen divided by total albumen.

Series 1

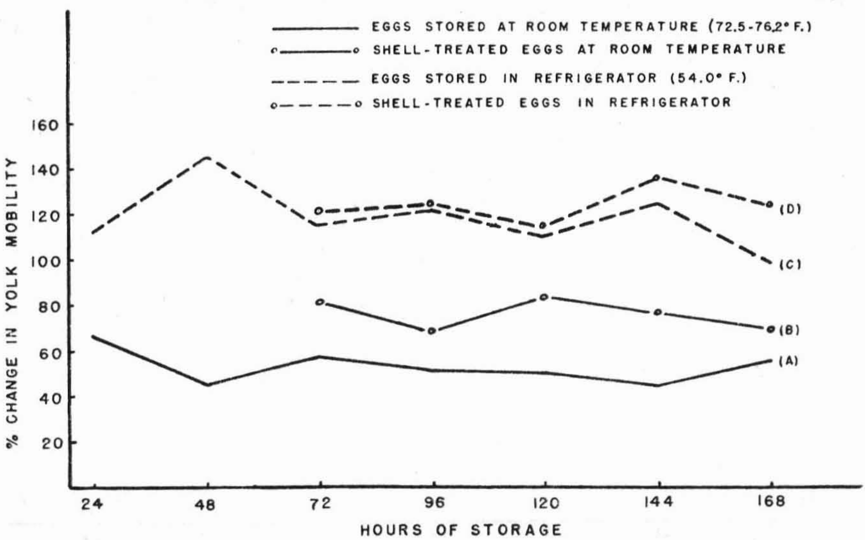
In this study, an attempt was made to determine the effects of direct sunlight and high air temperatures on egg quality. Fifty-four eggs from the pretest pullets were exposed to direct sunlight at an average temperature of 87.2° F. for a period of 4 hours. Other eggs were selected randomly and stored 4 hours in a refrigerator at 54° F. Similarly, 78 eggs were stored 8 hours in direct sunlight at an average air temperature of 82.5° F., while 33 eggs were stored in the refrigerator. The data obtained for yolk mobility, yolk index, and albumen index may be seen in table 2 (p. 22).

Since every egg employed in this study was produced by a pullet for which a fresh-egg standard had been established, it was possible to calculate the percentage changes in these indexes for the two sets of comparisons. The results of these calculations were as follows:

HOURS OF STORAGE	INDEX	STORED IN SUNLIGHT	STORED IN REFRIGERATOR	DIFFERENCE
		Percent	*Percent*	*Percent*
4	Yolk mobility	+42.5	+58.8	16.3
4	Yolk index	− 1.6	+ 2.2	3.8
4	Albumen index	− 8.0	− 0.9	7.1
8	Yolk mobility	+69.4	+71.4	2.0
8	Yolk index	+ 0.8	+ 3.8	3.0
8	Albumen index	− 6.9	+ 0.4	7.3

As may be seen, yolk mobility was greater in the refrigerated eggs after 4 and 8 hours of storage. Conversely, the yolk and albumen indexes were lower in the eggs stored in sunlight, the albumen index showing the greater change in both instances. Thus, the yolk index was not as readily influenced by an undesirable holding environment. After 8 hours of storage, eggs held in sunlight at 82.5° F. suffered a drop of 3.0 percent in yolk index and 7.3 percent in albumen index when compared with eggs stored a similar length of time at 54° F.

FIG. 1.* Percentage change in yolk mobility from fresh standard upon storage under various conditions.



*The legend shown in figure 1 also applies for figures 2, 3, 4, and 5.

Series 2

Following this pattern of investigation, eggs from the same pullets were stored for 24, 48, 72, 96, 120, 144, and 168 hours. The treatments, number of eggs observed per treatment, and indexes obtained for each period of storage are shown in table 3 (pp. 22–23).

When these data were converted into percentage changes (that is, loss or gain of the actual measurements from the average of 9.88 eggs per individual pullet) it was possible to plot them as shown in figures 1, 2, and 3. Figure 1 shows the percentage change in yolk mobility when eggs were stored from 1 to 7 days at either room or refrigerator temperatures. Furthermore, data are shown of eggs that were shell treated as described above and stored from 3 to 7 days. Yolk mobility was definitely affected by treatment, since the shell- and non-shell-treated, refrigerated eggs had significantly greater mobility ($P < 0.01$) than that of eggs held at room temperature. The variation from day to day, however, was not significant within treatments.

FIG. 2. Percentage change in yolk index from fresh standard upon storage under various conditions.

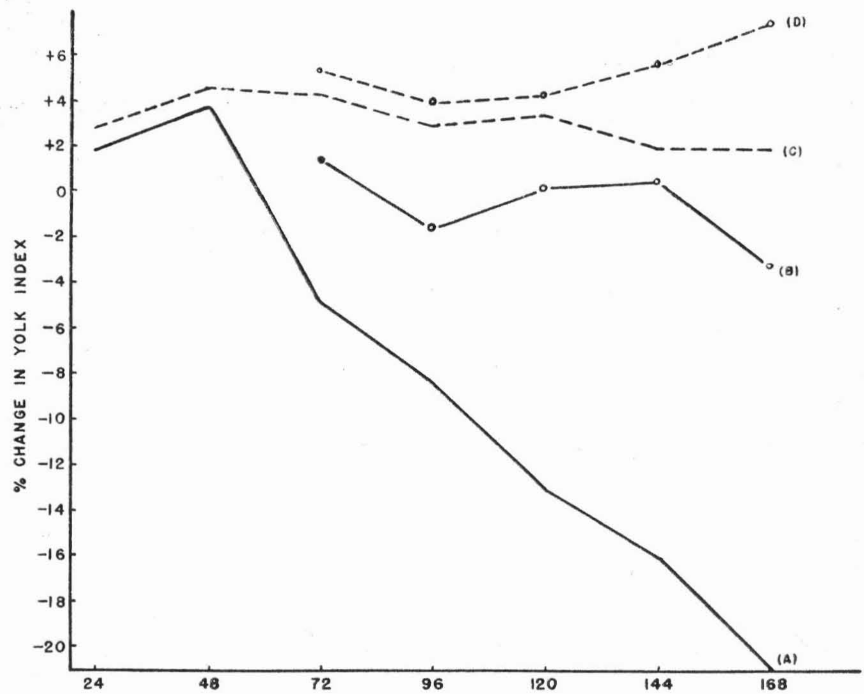


FIG. 3. Percentage change in daily albumen indexes from fresh standard.

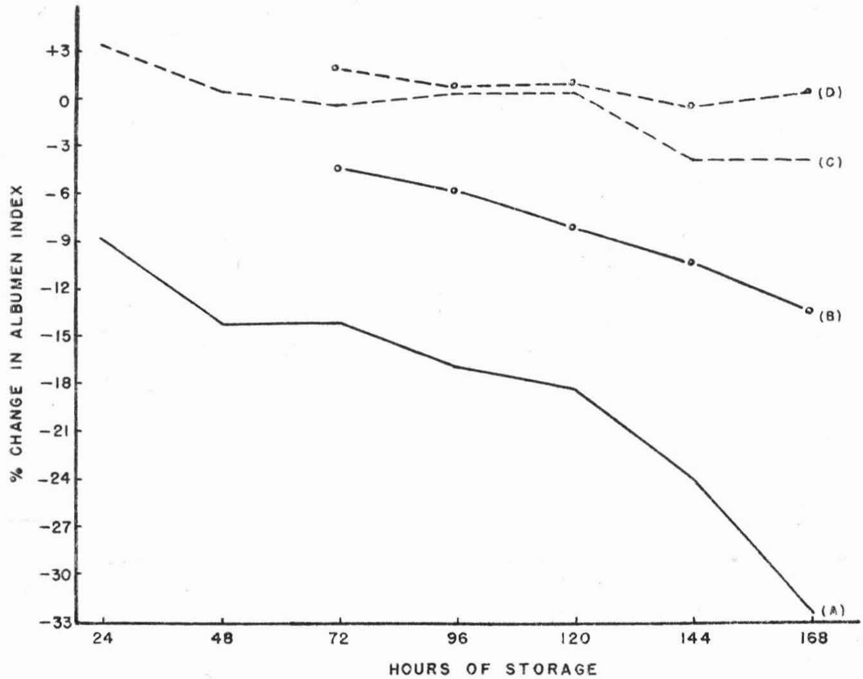


Figure 2 shows the percentage change in yolk index of these eggs. Whereas there was relatively little day-to-day change in eggs that were shell treated or refrigerated, there was a noteworthy change in the yolk index of eggs that were stored at room temperature more than 48 hours. Upon analysis, it was found that the changes in yolk indexes among the four treatments were highly significant ($P < 0.01$). The distinct drop in the yolk index of non-refrigerated, non-shell-treated eggs was the major source of this variation, and it was significantly greater than that of the other treatments.

The effects of storage, temperature, and shell treatment on the albumen index may be seen in figure 3. As shown, there was practically no change in the albumen index of eggs stored in the refrigerator at 54° F. during the duration of this study, shell treatment notwithstanding. Conversely, there was a definite effect of storage on eggs held at room temperature, the daily losses being greatest for the non-shell-treated eggs. Upon analysis, a highly significant difference ($P < 0.01$) existed among the four treatments, as well as within treatments.

FIG. 4. Changes in yolk index resulting from different methods of storage, after eggs were stored 7 days at 54° F.

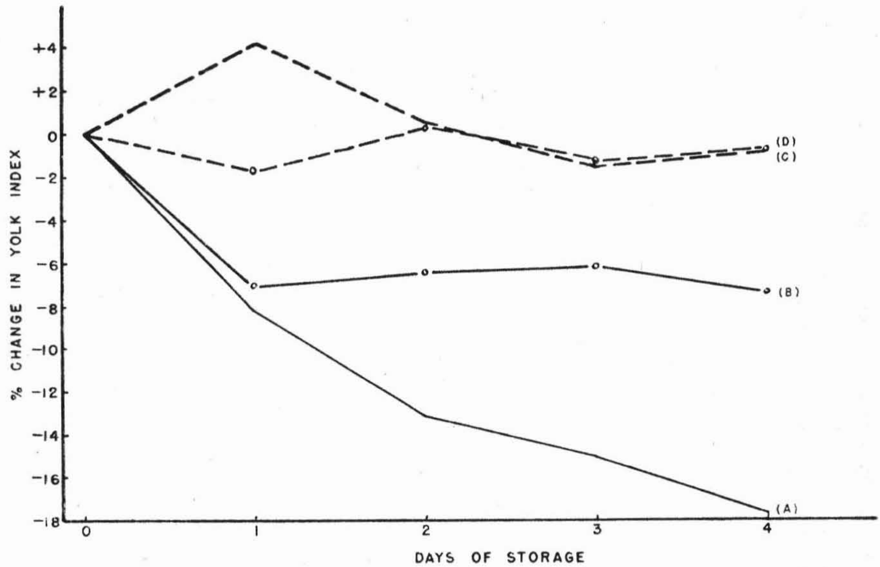
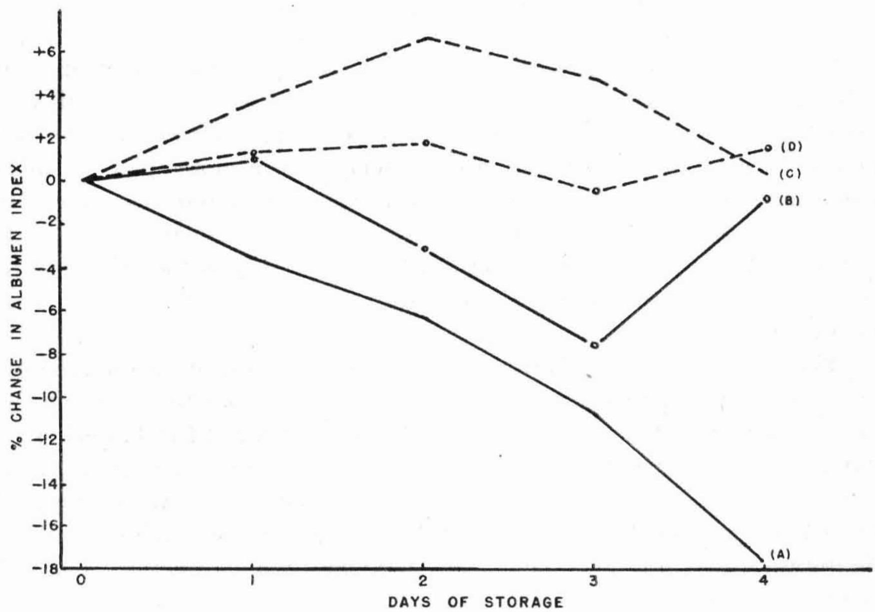


FIG. 5. Changes in albumen index resulting from different methods of storage, after eggs were stored 7 days at 54° F.



Series 3

In this phase of the investigation, a study was inaugurated to simulate conditions of egg storage after the eggs were retailed. In this study, all the eggs were placed in a refrigerator within ½ hour after oviposition and stored 7 days at 54° F. Half the eggs were treated with mineral oil prior to being placed in storage. After 7 days had passed, half the eggs from each set, both shell treated and non-shell treated, were removed from the refrigerator and stored at room temperature (72°–76° F.) from 24 to 96 hours. Comparable portions of each treatment were removed simultaneously. The eggs were opened at 1, 2, 3, and 4 days (following 7 days of storage in the refrigerator) and the yolk and albumen indexes determined. Table 4 shows the number of eggs opened and the data collected in this study.

In order to facilitate comprehension of table 4 (p. 24), figures 4 and 5 are also presented to clarify these data. As may be seen in figure 4, there was comparatively little change in the yolk indexes of refrigerated eggs, regardless of shell treatment. On the other hand, shell treatment definitely affected the rate of loss in quality of non-refrigerated eggs. After 4 days of storage at 72°–76° F., non-shell-treated eggs lost 17.9 percent of their original value (as determined at the end of 7 days' storage at 54° F.), whereas shell-treated eggs lost only 7.5 percent. Analysis showed that the variations between treatments as well as within treatments were highly significant ($P < 0.01$).

Similarly, figure 5 shows the changes in albumen indexes. Again, there was essentially no difference between shell-treated and non-shell-treated eggs when they were refrigerated. However, shell treatment significantly retarded the rate of change in the albumen index of non-refrigerated eggs. From the point of view of the retailer or housewife who does not refrigerate local eggs, these data emphasize the value of shell treatment.

Series 4

During recent times there has been a tendency for local fresh eggs to glut the market during the spring months, and, as a consequence, a few producers have attempted to store their eggs under "cold storage." This test was conducted to determine the changes that occur in the yolk and albumen indexes when eggs are stored for 31, 59, and 93 days. In all, 596 eggs were placed in storage at 36° F. (the only temperature available to us), and half of each group was shell treated prior to storage. All the eggs were candled and graded according to the U. S. Standards for Quality of individual shell eggs (Production and Marketing Administration, 1948) at the time of storage, and they were again classified when removed.

The eggs utilized in this study did not come from the pullets tested in series 1 through 3. The results are shown in table 5.

TABLE 5. Yolk and albumen indexes of eggs stored at 36° F. for 31, 59, and 93 days.

DURATION OF STORAGE	SHELL TREATED	NUMBER OF EGGS	YOLK INDEX	ALBUMEN INDEX
31 days	no	100	0.432	0.569
31 days	yes	100	0.417	0.542
59 days	no	100	0.430	0.534
59 days	yes	100	0.436	0.536
93 days	no	100	0.406	0.485
93 days	yes	96	0.424	0.452

The data were also summarized by individual eggs to determine the loss in grade incurred during the different storage periods (table 6).

TABLE 6. Changes in quality in eggs stored at 36° F. for 31, 59, and 93 days.

DURATION OF STORAGE	SHELL TREATED	NUMBER OF EGGS	EGGS SHOWING DROP IN GRADE: One grade	Two grades	Three grades	TOTAL GRADES DROPPED	PERCENTAGE CHANGE IN ONE GRADE
31 days	no	100	20	1	0	22	22.0
31 days	yes	100	15	3	0	21	21.0
59 days	no	100	40	0	1	43	43.0
59 days	yes	100	31	0	1	34	34.0
93 days	no	100	71	12	1	98	98.0
93 days	yes	96	57	4	1	68	70.8

TABLE 7. Candling grade and accuracy in detecting meat and blood spots in fresh eggs.

CLASSIFICATION	FREQUENCY OF MEAT AND BLOOD SPOT EGGS: Grade 1 (AA) *		Grade 2 (A) *		Grade 3 (B) *	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Meat and blood spot eggs detected by candling	7	13.2	33	62.3	13	24.5
Meat and blood spots not detected by candling	71	44.9	72	45.6	15	9.5
Easily seen	40	43.0	42	46.2	10	10.8
Pin point	31	47.7	29	44.6	5	7.7

*United States standards for quality of individual shell eggs, 1948.

It is apparent, both from the data on yolk and albumen indexes shown in table 5 and from the total grades dropped shown in table 6, that there was little benefit from shell treatment among eggs stored 31 and/or 59 days. However, shell treatment helped maintain quality among the eggs stored 93 days. Whereas shell-treated eggs lost 71 percent of a grade in 3 months, the non-shell-treated eggs lost 98 percent of a grade. Furthermore, the yolk index was definitely lower in the non-shell-treated group. Contrary to all other similar comparisons in this study, the albumen indexes for non-shell-treated eggs were higher among those stored 31 and 93 days. The reason for this non-conformity is unknown.

The following observations were made on the two groups of eggs that had been stored for 93 days:

1. The albumen of shell-treated eggs was more watery and somewhat cloudier in appearance.
2. There was less thick albumen in the shell-treated eggs; and it appeared to be concentrated in two clumps in the regions of the chalazae.
3. The vitelline membranes of shell-treated eggs did not tear as readily.
4. It was easier to separate the albumen of shell-treated eggs. In the non-shell-treated eggs, the thick albumen was gelatin-like immediately around the yolk and difficult to remove.

Detection of Meat and Blood Spots

During the course of this investigation, there was an opportunity to evaluate the relationship of candling grade to meat and blood spots. Of 362 eggs containing meat and blood spots, it was found that only 21.5 percent were detected by candling. As may be seen in table 7, most of the eggs containing meat and blood spots detected by candling were either in grades A or B. Only 13.2 percent of detected eggs were graded AA. Among the undetected eggs, 44.9 percent of the eggs were graded AA. It would appear that the primary cause of error was density of albumen. As shown in the two bottom lines of table 7, the frequency of meat and blood spots in grades AA, A, and B was approximately the same for meat and blood spots that were either easily seen or pin point in size.

DISCUSSION AND CONCLUSIONS

It has been possible to describe fresh eggs in statistical terms. From an analysis of 988 eggs, a fresh egg has a yolk mobility of 1.61 ± 0.023, a yolk index of 0.373 ± 0.014, and an albumen index of 0.549 ± 0.017. Such an egg may be described also as follows: upon candling, the yolk is but dimly visible and slightly mobile; when the egg is opened, the yolk height is 37.3 percent of the diameter, while the percentage thickness of total albumen is 54.9.

It has been possible to follow the changes in yolk and albumen indexes during different periods of storage ranging from 4 hours to 93 days. It was observed that eggs deteriorate rapidly in Hawaii. In terms of the indexes utilized in this study, eggs exposed to sunlight 4 hours lost 3.8 percent in yolk index and 7.1 percent in albumen index. Eggs exposed to sunlight 8 hours lost about the same. Thus it is apparent that frequent collections and rapid cooling of table eggs are imperative if eggs are to retain maximum quality.

In order to determine the rate at which eggs deteriorate in quality during a period of 7 days, thereby simulating the period during which eggs normally move to market, 1,889 eggs were opened and measurements recorded. From this study the following trends appear evident:

1. In every comparison, refrigerated eggs exhibited greater yolk-mobility changes than comparable room eggs.

2. In every comparison, shell-treated eggs exhibited greater yolk mobility changes than non-shell-treated eggs.

3. In every comparison, the non-shell-treated eggs stored at room temperature showed the smallest percentage change in yolk mobility, and the refrigerated, shell-treated eggs exhibited the greatest percentage increase.

4. After the second day of storage, the yolk index of room eggs rapidly became smaller, whereas eggs stored in a refrigerator at 54° F. showed practically no change in yolk index through 7 days of storage.

5. Shell treatment of non-refrigerated eggs definitely reduced the daily loss in yolk index. In every comparison, however, refrigerated eggs, both shell and non-shell treated, exhibited a lesser loss in yolk index than shell-treated, non-refrigerated eggs.

6. The changes in albumen indexes were greater than those observed in yolk indexes.

7. In every comparison, refrigerated eggs showed a lesser loss in albumen index than did non-refrigerated eggs. After 24 hours there was a difference of 12.2 percent, whereas at the end of 7 days the difference was 28.2 percent.

8. Shell treatment of non-refrigerated eggs definitely reduced the daily

loss in albumen index. In every comparison, however, refrigerated eggs, both shell and non-shell treated, exhibited a lesser loss in albumen index than the shell-treated, non-refrigerated eggs.

9. Shell treatment of eggs that are to be refrigerated for 7 days or less does not appear warranted.

10. Refrigeration at 36° F. of non-shell-treated eggs appears to be superior to refrigeration at 54° F., particularly with regard to the albumen index (table 3). These differences do not justify the storage of eggs at 36° F. if eggs are to be marketed within 7 days.

From a study designed to simulate conditions of storage after eggs are retailed (series 4), the following conclusions may be drawn:

1. The albumen and yolk indexes were not materially depressed when either shell-treated or non-shell-treated eggs were stored under refrigeration from the seventh to eleventh day. Thus, there is no need to shell treat eggs that will be refrigerated by the producer, the retailer, and the customer.

2. When eggs were stored at room temperature, however, shell treatment definitely reduced the rate at which the two indexes dropped. It is suggested that the large drop in albumen index for the shell-treated eggs on the third day (figure 5) was due to sampling deviation.

3. Non-shell-treated eggs stored at room temperature rapidly lost quality. After 4 days, the yolk index dropped 17.9 percent and the albumen index 17.8 percent. It would appear that shell treatment of eggs is justified if housewives are not made aware of the importance of keeping eggs under refrigeration.

A comparison of shell treatment versus non-shell treatment was undertaken to determine the advisability of shell treating local storage eggs. The results of this study suggested that there was no real benefit in shell-treating eggs that were stored 2 months or less. However, shell-treated eggs stored for 93 days revealed a lower candling grade loss (.27 grade), and, consequently, this difference is of great monetary value, particularly when many eggs are stored. It was also observed that shell-treated eggs contained less thick albumen (3.3 percent) which tended to be somewhat cloudy in appearance. These defects may affect the advantages of shell treatment as considered in this study.

The following practical suggestions are offered for consideration:

1. The producer should collect eggs frequently each day. Three or four collections per day are not too many to ensure maximum egg quality.

2. The producer should store eggs in wire baskets and reduce animal heat as rapidly as possible. Never store eggs at room temperature, since it

was observed that the albumen index of non-shell-treated eggs dropped 8.8 percent within 24 hours, and 14.1 percent within 48 hours. If regrigerator or cooler facilities are not available, eggs should be marketed at least every other day.

3. Shell treatment of fresh eggs is not warranted when eggs are properly refrigerated; this applied to eggs stored from 1 to 59 days.

4. However, shell treatment appears justified under the following conditions:

a. When eggs are stored for more than 2 months. Shell-treated eggs stored 93 days appeared to have a higher candling grade than non-shell-treated eggs.

b. When eggs are not refrigerated and not marketed in less than 2 days. It was found that the quality of table eggs stored at room temperature was higher whenever they were shell treated. The value of shell treatment was apparent among eggs stored only 3 days at room temperature, and its value increased with each passing day.

c. As a practical means of maintaining quality when eggs pass through a diverse channel of trade, with several parties handling the eggs between producer and consumer.

LITERATURE CITED

(1) ALMQUIST, H. J.
1933. RELATION OF THE CANDLING APPEARANCE OF EGGS TO THEIR QUALITY. Calif. Agr. Expt. Sta. Bul. 561: 1–31.

(2) BERRY, L. N.
1950. A BREEDING PROGRAM FOR IMPROVING INTERIOR EGG QUALITY. New Mexico Agr. Expt. Sta. Bul. 357: 1–10.

(3) BICE, C. M.
1947. PRESERVE THE SUPERIOR QUALITY OF "FRESH-LAID" HAWAIIAN EGGS! Hawaii Agr. Ext. Cir. 80: 1–2.

(4) CANHAM, A. S.
1933. WATERY WHITES OF EGGS. Chem. Abs. 28: 2424.

(5) FUNK, E. M.
1935. THE COOLING OF EGGS. Missouri Agr. Expt. Sta. Bul. 350: 1–15.

(6) HOLST, W. F., and H. J. ALMQUIST.
1931*a*. MEASUREMENT OF DETERIORATION IN THE STORED HEN'S EGG. Hilgardia 3 (6): 49–60.

(7) ——— and ———.
1931*b*. DISTRIBUTION OF SOLID MATTER IN THICK AND THIN WHITE. Hilgardia 3 (6): 45–48.

(8) HUNTER, J. A., A. VAN WAGENEN, and G. O. HALL.
1934. STUDIES IN INTERIOR EGG QUALITY. Poultry Sci. 13: 314–315.

(9) JULL, M. A., and T. C. BYERLY.
1934. Yearbook of Agriculture, 195–197.

(10) KNOX, C. W., and A. B. GODFREY.
1934. VARIABILITY OF THICK ALBUMEN IN FRESH LAID EGGS. Poultry Sci. 13: 18–22.

(11) ——— and ———.
1940. FIVE YEARS OF BREEDING FOR HIGH AND LOW PERCENTAGE OF THICK ALBUMEN IN THE EGGS OF RHODE ISLAND REDS. Poultry Sci. 19: 291–294.

(12) LORENZ, F. W., and H. J. ALMQUIST.
1934. DETERMINATION OF THE PERCENTAGE OF FIRM WHITE. U. S. Egg & Poultry Mag. 40 (11) : 30–33.

(13) ——— and ———.
1936. SEASONAL VARIATIONS IN EGG QUALITY. Poultry Sci. 15: 14–18.

(14) MORRIS, T. B., C. F. PARRISH, and W. G. ANDREWS.
1950. CONSERVING EGG QUALITY. North Carolina Ext. Serv. Folder 80: 1–2.

(15) OLSEN, M. W.
1939. EFFECT OF HIGH TEMPERATURE FOR SHORT PERIODS ON THE QUALITY OF INFERTILE EGGS. Poultry Sci. 18: 123–124.

(16) PENNINGTON, M. E., M. J. TRUE, A. D. RICH, and A. A. KIESS.
1934. YOLK INDEX AND THICK WHITE IN EGGS GRADED BY CANDLING FOR INTERIOR QUALITY. U. S. Egg & Poultry Mag. 40 (4) : 43–50.

(17) SHARP, P. F.
1929. WHAT ONE WEEK MAY DO TO AN EGG. U. S. Egg & Poultry Mag. 35 (6) : 14–17.

(18) ———.
1934. THE CONDITION OF THE APPARENT THICK WHITE AS AN IMPORTANT FACTOR IN STUDYING THE QUALITY OF EGGS. U. S. Egg & Poultry Mag. 40 (11) : 33–37.

(19) SKOGLUND, W. C., and A. E. TOMHAVE.
1941. FREQUENCY OF GATHERING EGGS AND EFFECT UPON INTERIOR EGG QUALITY. Poultry Sci. 22: 322–326.

(20) ST. JOHN, J. L.
1936. WHAT IS A "WATERY" EGG? Poultry Sci. 15: 79–82.

(21) ——— and E. L. GREEN.
1930. THE COLLOIDAL STRUCTURE OF EGG WHITE AS INDICATED BY PLASTICITY MEASUREMENTS. Jour. Rheol. 1: 484.

(22) THISTLE, A.
1946. SUGGESTIONS FOR THE RETAILER ON COMPLIANCE WITH HAWAII'S EGG LAW AND THE NEW RULES AND REGULATIONS PROMULGATED UNDER ITS AUTHORITY. Division of Marketing, Board of Commissioners of Agriculture and Forestry, Honolulu, Hawaii. April (no number).

(23) VAN WAGENEN, A., and H. S. WILGUS, JR.
1935. DETERMINATION AND IMPORTANCE OF THE CONDITION OF FIRM ALBUMEN IN STUDIES OF EGG WHITE QUALITY. Jour. Agr. Res. 51: 1129–1138.

TABLE 2. The effect of storage on quality of fresh eggs.

METHOD OF HANDLING	NUMBER OF EGGS	$\bar{X}$ AIR TEMPERATURE	AGE OF EGGS WHEN ANALYZED	$\bar{X}$ YOLK MOBILITY		$\bar{X}$ YOLK INDEX		$\bar{X}$ ALBUMEN INDEX	
				Actual	Theoretical fresh	Actual	Theoretical fresh	Actual	Theoretical fresh
		°F.	Hours						
Sunlight	54	87.2	4	2.28	1.60	0.368	0.374	0.506	0.550
Refrigerator	53	54.0	4	2.62	1.65	0.379	0.371	0.545	0.550
Sunlight	78	82.5	8	2.66	1.57	0.374	0.371	0.514	0.552
Refrigerator	33	54.0	8	2.88	1.68	0.381	0.367	0.561	0.559

TABLE 3. The effects of temperature, storage, and shell treatment on certain egg indexes.

METHOD OF HANDLING	NUMBER OF EGGS	$\bar{X}$ AIR TEMPERATURE	AGE OF EGGS WHEN ANALYZED	$\bar{X}$ YOLK MOBILITY		$\bar{X}$ YOLK INDEX		$\bar{X}$ ALBUMEN INDEX	
				Actual	Theoretical fresh	Actual	Theoretical fresh	Actual	Theoretical fresh
		°F.	Hours						
Room temperature	92	72.5	24	2.54	1.52	0.377	0.370	0.500	0.548
Refrigerator	24	54.0	24	3.08	1.45	0.385	0.375	0.551	0.533
Room temperature	93	73.1	48	2.40	1.64	0.361	0.348	0.476	0.554
Refrigerator	22	54.0	48	3.68	1.50	0.397	0.380	0.551	0.548
Room temperature	92	73.0	72	2.38	1.51	0.355	0.373	0.479	0.558
Refrigerator	49	54.0	72	3.55	1.64	0.388	0.372	0.551	0.553
Room temperature Shell treated	91	73.3	72	2.89	1.60	0.379	0.373	0.525	0.549
Refrigerator Shell treated	50	54.0	72	3.62	1.64	0.387	0.367	0.568	0.557
Room temperature	88	75.0	96	2.32	1.54	0.329	0.359	0.462	0.556
Refrigerator	50	54.0	96	3.48	1.57	0.381	0.370	0.558	0.555
Room temperature Shell treated	89	75.0	96	2.62	1.55	0.366	0.372	0.519	0.551
Refrigerator Shell treated	51	54.0	96	3.62	1.61	0.390	0.375	0.571	0.567

TABLE 3. The effects of temperature, storage, and shell treatment on certain egg indices.—*Continued*

METHOD OF HANDLING	NUMBER OF EGGS	$\bar{X}$ AIR TEMPERATURE	AGE OF EGGS WHEN ANALYZED	$\bar{X}$ YOLK MOBILITY		$\bar{X}$ YOLK INDEX		$\bar{X}$ ALBUMEN INDEX	
				Actual	Theoretical fresh	Actual	Theoretical fresh	Actual	Theoretical fresh
Room temperature	90	74.5	120	2.37	1.58	0.324	0.373	0.450	0.551
Refrigerator	50	54.0	120	3.34	1.59	0.383	0.370	0.553	0.551
Room temperature Shell treated	90	74.5	120	2.82	1.54	0.369	0.368	0.494	0.539
Refrigerator Shell treated	50	54.0	120	3.48	1.62	0.388	0.372	0.558	0.552
Room temperature	89	75.1	144	2.33	1.62	0.313	0.373	0.413	0.544
Refrigerator	50	54.0	144	3.46	1.54	0.375	0.368	0.536	0.557
Room temperature Shell treated	90	75.1	144	2.82	1.60	0.373	0.371	0.492	0.549
Refrigerator Shell treated	50	54.0	144	3.72	1.58	0.392	0.371	0.557	0.560
Room temperature	89	75.7	168	2.48	1.61	0.294	0.372	0.371	0.549
Refrigerator	89	54.0	168	3.29	1.67	0.379	0.372	0.529	0.550
Room temperature Shell treated	89	76.2	168	2.68	1.59	0.361	0.373	0.478	0.551
Refrigerator Shell treated	91	54.0	168	3.54	1.59	0.399	0.371	0.559	0.556
Refrigerator	90	36.0	168	3.71	1.57	0.382	0.371	0.570	0.548
Refrigerator Shell treated	91	36.0	168	3.78	1.59	0.396	0.372	0.567	0.549

TABLE 4. Yolk and albumen indexes and percentage change therein when eggs were stored 7 to 11 days.

HOURS STORED AFTER 7 DAYS IN REFRIGERATOR AT 54° F.	METHODS OF HANDLING*	NUMBER OF EGGS	YOLK INDEX	CHANGE IN YOLK INDEX	CHANGE FROM 7 DAYS' INDEX	ALBUMEN INDEX	CHANGE IN ALBUMEN INDEX	CHANGE FROM 7 DAYS' INDEX
					Percent			*Percent*
0	A	89	0.379			0.529		
0	B	91	0.399			0.559		
24	A	50	0.395	+0.016	+ 4.22	0.549	+0.020	+ 3.78
24	B	50	0.392	−0.007	− 1.75	0.566	+0.007	+ 1.25
24	C	50	0.348	−0.031	− 8.18	0.510	−0.019	− 3.59
24	D	50	0.371	−0.028	− 7.02	0.565	+0.006	+ 1.07
48	A	50	0.381	+0.002	+ 0.53	0.565	+0.036	+ 6.80
48	B	50	0.400	+0.001	+ 0.25	0.570	+0.011	+ 1.97
48	C	50	0.329	−0.050	−13.19	0.496	−0.033	− 6.24
48	D	50	0.373	−0.026	− 6.52	0.542	−0.017	− 3.04
72	A	50	0.373	−0.006	− 1.58	0.555	+0.026	+ 4.91
72	B	50	0.394	−0.005	− 1.25	0.556	−0.003	− 0.54
72	C	50	0.322	−0.057	−15.04	0.472	−0.057	−10.78
72	D	50	0.374	−0.025	− 6.26	0.517	−0.042	− 7.51
96	A	50	0.376	−0.003	− 0.79	0.532	−0.003	+ 0.57
96	B	50	0.396	−0.003	− 0.75	0.568	−0.009	+ 1.61
96	C	50	0.311	−0.068	−17.94	0.435	−0.094	−17.77
96	D	50	0.369	−0.030	− 7.52	0.554	−0.005	− 0.89

*Methods of handling: A=non-shell-treated eggs stored in refrigerator at 54° F.; B=shell-treated eggs stored in refrigerator at 54° F.; C=non-shell-treated eggs stored at room temperature (72°-76° F.); and D=shell-treated eggs stored at room temperature (72°-76° F.).

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